Clean Transportation Fuels in the United States

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This presentation addresses the current status and future projections of transportation fuel requirements in the United States. Specifically, the discussion focuses on transportation fuel sources, driving forces for changes in fuels, current regulations and standards, and clean fuel production and refining technologies for gasoline and diesel fuel.

Liquids derived from oil fuel 97% of the United States transportation sector. The remaining 3% of our transportation fuel is comprised of oxygenates, compressed natural gas and some specialty additives. In the future we expect some incremental increases in fuels from biomass, natural gas liquids, and perhaps liquids from coal. However, most transportation fuels will still be derived from oil.

Major changes in vehicle fleet composition are anticipated over the next two decades: most significantly, thee will be more diesel-powered vehicles and fuel cell-powered vehicles with onboard fuel reformers. Even with greatly more fuel-efficient vehicles, the United States Energy Information Administration predicts fuel demand will increase by about 50% by the year 2020. Although vehicle manufacturers have made substantial progress in reducing emissions per vehicle-mile, the total amount of emissions is increasing because the population is increasing and the economy is growing with a resulting increase in the number of vehicles and total miles driven.

Mandated limitations on tailpipe emissions are the major driving force for changing the fuel composition in the United States. Simultaneously, refiners are facing increasing environmental regulations on products and on emissions from their fuel production operations.

Transportation accounts for one-third of the total U.S. emissions of man-made carbon dioxide. Buildings and industry account for the bulk of the remainder. Over the next 20 years, transportation is expected to become the leading carbon emitter in the United States, exceeding 690 million metric tons in 2020 compared with 450 million metric tons today. Likewise, transportation produces major fractions of carbon monoxide, nitrogen oxide and volatile organic compound emissions today.

The move to clean fuels in the United States started in 1978 with the removal of lead as a gasoline additive. Later summer and winter gasoline was regulated to control fuel volatility, then Reformulated Gasoline was introduced. Now sulfur and aromatic compound reductions are hot topics in a number of countries. The California Air Resources Board (CARB) has set the strictest local fuel regulations in the United States. The current emphasis is sulfur removal because sulfur poisons the emissions control catalyst in nitrogen oxide control devices mandated for the near future. The end goal, by 2010, is to require the same emissions limits for vehicles independent of fuel type or engine system. Diesel engines are especially challenged to match gasoline system emissions with regard to nitrogen oxides and particulate matter. Note that the standards expressed in grams per brake horsepower-hour normalize pollutant concentrations to be independent of engine systems.

The United States continues along the path to cleaner fuels for both gasoline and diesel fuel. However, at the same time the demand for cleaner fuels is increasing, the feedstocks to U.S. refineries are becoming heavier and more sulfur-laden. Sulfur in feed is increasing at 270 ppm/year and API gravity is decreasing by 0.16 degrees/year. In 2000 the average feed to U.S. refineries was 1.35% sulfur and 31 degrees API gravity. European refinery feed, by comparison, was sweeter at 1% sulfur and 35 degrees API gravity. In the future we expect to see more emphasis on other aspects of emissions-related issues

including low sulfur engine lubricants, jet fuel and home heating oil specifications, drivability index and others.

For the new U.S. Environmental Protection Agency gasoline regulations, the point of analysis is at the fuel pump at an average of 30 ppm sulfur with a maximum of 80 ppm.

For diesel, however, the 15 ppm sulfur maximum is anywhere downstream of the refinery, including at the fuel pump. This greatly complicates delivery of diesel fuel using the existing distribution infrastructure of common carrier pipelines, tanks, and delivery trucks at less than 15 ppm.

Low sulfur gasoline technology is well in hand. The $8 billion capital cost estimate does not include totals for distribution infrastructure improvements that may be required.

The U.S. economy runs on diesel fuel. Trucks deliver most commodities in the United States. Fuel is only part of the equation to achieve low emissions and maintain efficiency and operability. Emissions controls for spark ignition gasoline engines have been widely used for 20 years. However, development of emissions controls for compression ignition diesel engines has not advanced as fast as hoped and may not be fully implemented by 2006 when 15 ppm sulfur diesel is mandated. Low sulfur diesel not only facilitates effective nitrogen oxide

absorption, but also assists in reduction of particulate matter in diesel exhaust. The Environmental Protection Agency will review diesel system technology in 2004 to determine if any changes may be required for implementation of the new regulations.

Currently, higher sulfur crude is processed to obtain 350 ppm average sulfur diesel fuel and relies on hydrocracked stock blended with some straight run being sent directly to the highway diesel pool. The bulk of the straight run is sent to the hydrotreater with higher sulfur cracked stock and coker distillate. The bulk of the total sulfur is contained in the cracked stock and coker distillate.

The new 2006 mandate for 15 ppm maximum sulfur diesel (7 – 10 ppm average) would likely require all the hydrocracked stock and all the straight run to go to new high pressure, high temperature two-stage distillate desulfurization units. With current technology this will likely necessitate two or more hydrogenation units in series to achieve the desired sulfur levels with heavier crude oils. The cracked stock and coker distillate will have to seek other markets. The new hydrodesulfurization units will need massive amounts of hydrogen, will be expensive, and can only be built by a few qualified companies.

Other options for desulfurization technology exist, but are unproven commercially. Zeolite adsorption is being tested at the pilot scale and only requires nearly stochiometric hydrogen. Thus it has great cost advantages.

Likewise, selective partial oxidation and separation is under laboratory development, but not close to commercialization. Refiners will want to minimize risk and be drawn to hydrodesulfurization technology, but zeolite adsorption may offer acceptable risks by the time investment decisions are required.

Costs to meet the new standards are estimated to be $8 billion in capital costs for installing desulfurization technology with a resultant additional 7 to 15 cents per gallon fuel cost. Again, these costs do not reflect any distribution infrastructure upgrades. Major issues remain for diesel, however. Nitrogen absorbers are not fully developed yet; lubrication oils alone contribute about 8 ppm sulfur to tailpipe emissions; and the fuel distribution system may not be able to maintain 15 ppm sulfur in diesel to the pump.

From this discussion we can conclude that low sulfur gasoline production by 2004 is not a technological issue and is well in hand; environmental permitting, specialty materials, and adequate skilled labor are persistent issues. Gasoline and alcohols are the most likely candidates for powering automotive fuel cells.

The production of diesel fuel by 2006 is more problematic. The only commercially proven sulfur reduction technology is a high cost one, but there is still hope for breakthrough technology in time for implementation. It may be uneconomical to produce low sulfur diesel fuel from some high sulfur crudes.

Some refineries may be too costly to convert, creating shortages in production capacity. Many infrastructure questions remain to be tested and resolved.

The implementation of low sulfur gasoline may impact available engineering and construction resource availability, slowing design and construction of diesel desulfurization units. In addition Canada and Europe are on similar time paths as the U.S. for producing clean fuels, further exacerbating these resource constraints. Finally, other regulations may restrict markets for residual high sulfur distillate leaving the utilization of a third of distillate production not well defined. If any of these issues cannot be resolved in the near term, the U.S. may not achieve the desired 15 ppm diesel implementation until well after 2006.

In summary, petroleum will continue to be the primary source of transportation fuel. Gas-to-liquid and biodiesel fuels will make some market entry, but not a large one in the foreseeable future. We need more economical technologies to produce low sulfur diesel fuels from heavy, sour crudes. We should expect mandated changes in the sulfur content specifications for jet fuel, lubricants, and off-road diesel in the future. Similarly, specifications for aromatic content, boiling range, toxics and oxygenates will likely be further restricted.

Some other uncertainties could change the fuel usage patterns projected here. If, for example, the EPA mandates higher fuel efficiency vehicles, the auto industry would likely switch from gasoline to diesel engines to power larger

vehicles. This would drive diesel demand up significantly while reducing gasoline demand. Such a change would create more stress on the fuel system since low sulfur diesel technology is less certain than low sulfur gasoline technology.

We anxiously watch events unfold in the near future. The eventual path is strongly dependent on technology development and regulatory actions.